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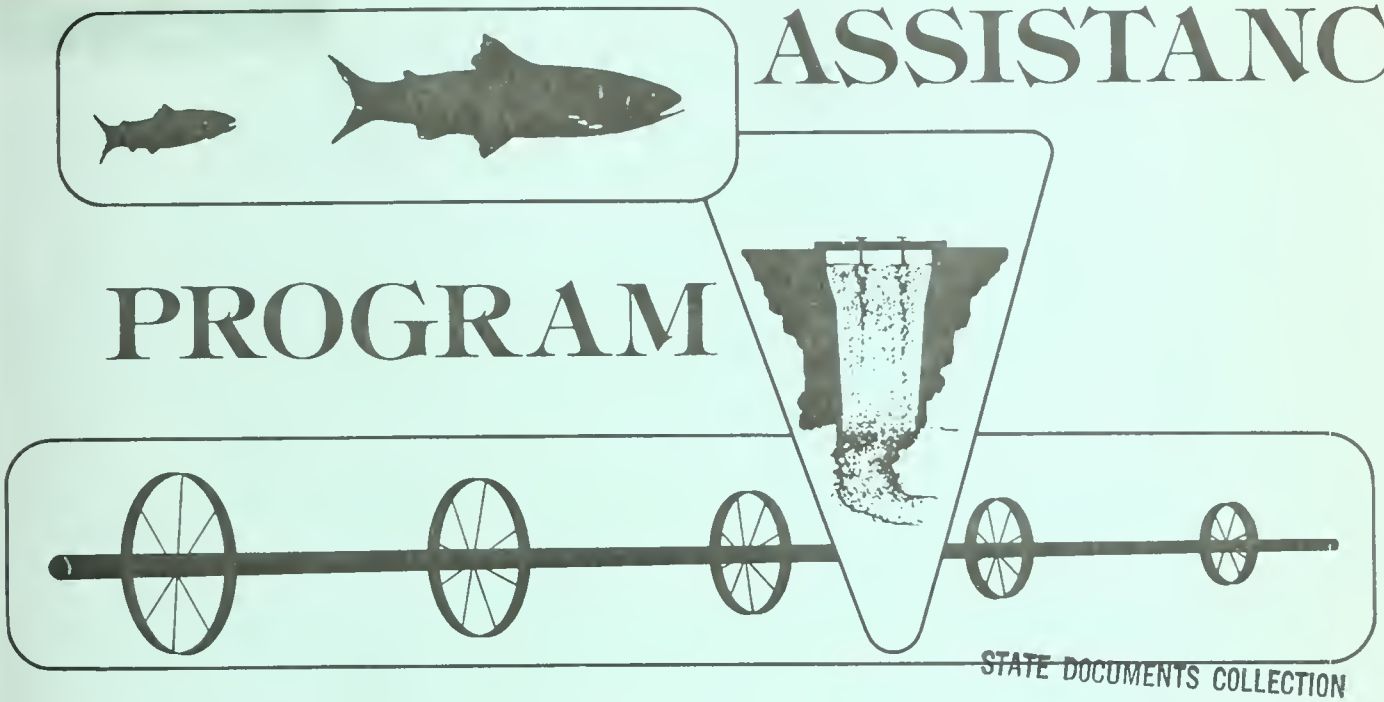

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Prefeasibility Report
on

MUSSELSHELL RIVER WATER DEVELOPMENT ASSOCIATION

Proposed Offstream Storage Reservoir

MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION

WATER RESOURCES DIVISION

NOVEMBER 1978

DNRC

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TECHNICAL ASSISTANCE PROGRAM

MUSSELSHELL RIVER WATER DEVELOPMENT ASSOCIATION PROPOSED OFFSTREAM STORAGE RESERVOIR

Prepared By

Norman Barnard, Civil Engineer
Bill Long, Resource Economist

Department of Natural Resources and Conservation
Water Resources Division
32 S. Ewing
Helena, Montana
449-2872

November 1978

DATE DUE

MAR 17 2005

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INTRODUCTION

Increased demand for irrigation water has revealed a need for additional storage in the Musselshell River Basin. The program of Technical Assistance to Water Resources Projects, administered by the Department of Natural Resources and Conservation (DNRC), assists local groups by completing preliminary investigation (prefeasibility) reports of proposed multipurpose water and related land development projects. Through this program, DNRC became involved in investigating two potential offstream storage sites in the Musselshell River Basin.

The DNRC was initially contacted by State Senator Jack Galt and later by State Representative Hershel M. Robbins and Mr. Thomas Ask concerning the feasibility of developing supplemental irrigation water for the lower Musselshell River Basin. Personnel from DNRC met with members of the Musselshell River Water Development Association (MRWDA), an organization formed to promote interest and obtain assistance in the development of irrigation water storage projects, to discuss their plans and desires and to inform them of the programs DNRC has available for assistance.

On May 23, 1977, DNRC received a written request for assistance (appendix A) from the MRWDA. Two sites, Willow Creek near Roundup and Woman's Pocket (Dry Lake) near Lavina, had been selected by the association for investigation. Both sites are offstream from the Musselshell River and would require either pumping or canal diversion to provide a water supply adequate for storage. Geographically, the Willow Creek site has greater potential because of its proximity to the lands requiring supplemental water and because of the increased flow in the Musselshell at Roundup compared to that at Lavina. This prefeasibility report evaluates the Willow Creek site in its entirety and compares Woman's Pocket site data from DNRC files.

EVALUATION OF WILLOW CREEK SITES

Location

The proposed Willow Creek reservoir site is approximately three miles northeast of Roundup in Township 8 North, Range 26 East, Section 4, on Willow Creek, a tributary of the Musselshell River entering the Musselshell about five-and-a-half miles east of the city. Five possible sites (sites A through E) were located in a two-and-a-half mile reach of the creek between the mouth and the first major fork (figure 1).

Method of Evaluation

All computations were based on measurements taken from the United States Geological Survey (USGS) stream-gage records and advance quadrangle maps. Using dam centerline profile and reservoir surface area measurements, curves of elevation (feet) versus embankment volume (cubic yards), storage capacity (acre-feet), and water surface area (acres) were plotted. These curves for sites A through E are included in appendix B. After reviewing power costs, pipe costs, and these curves, it was determined that the least expensive site for the dam was site A; further discussion will refer to this site.

Fourteen combinations of reservoir storage capacities and numbers of pumps were studied at site A to determine the firm annual yield (acre-feet available for delivery every year). Some of the combinations can be seen in Table 1. The pumping season for the studies was from October 1 through March 31 (182 days) with the assumption that any water available for pumping outside this period would compensate for losses experienced during the season due to ice or mechanical problems. The firm annual yield was calculated assuming that when the average daily flow was greater than or equal to an even multiple of one pump's capacity, that number of pumps was operated for twenty-four hours. The total volume of water pumped each year by this method was calculated for the twenty-eight years of record. By adding this yearly volume to carry-over storage

FIGURE 1. LOCATION OF WILLOW CREEK SITES

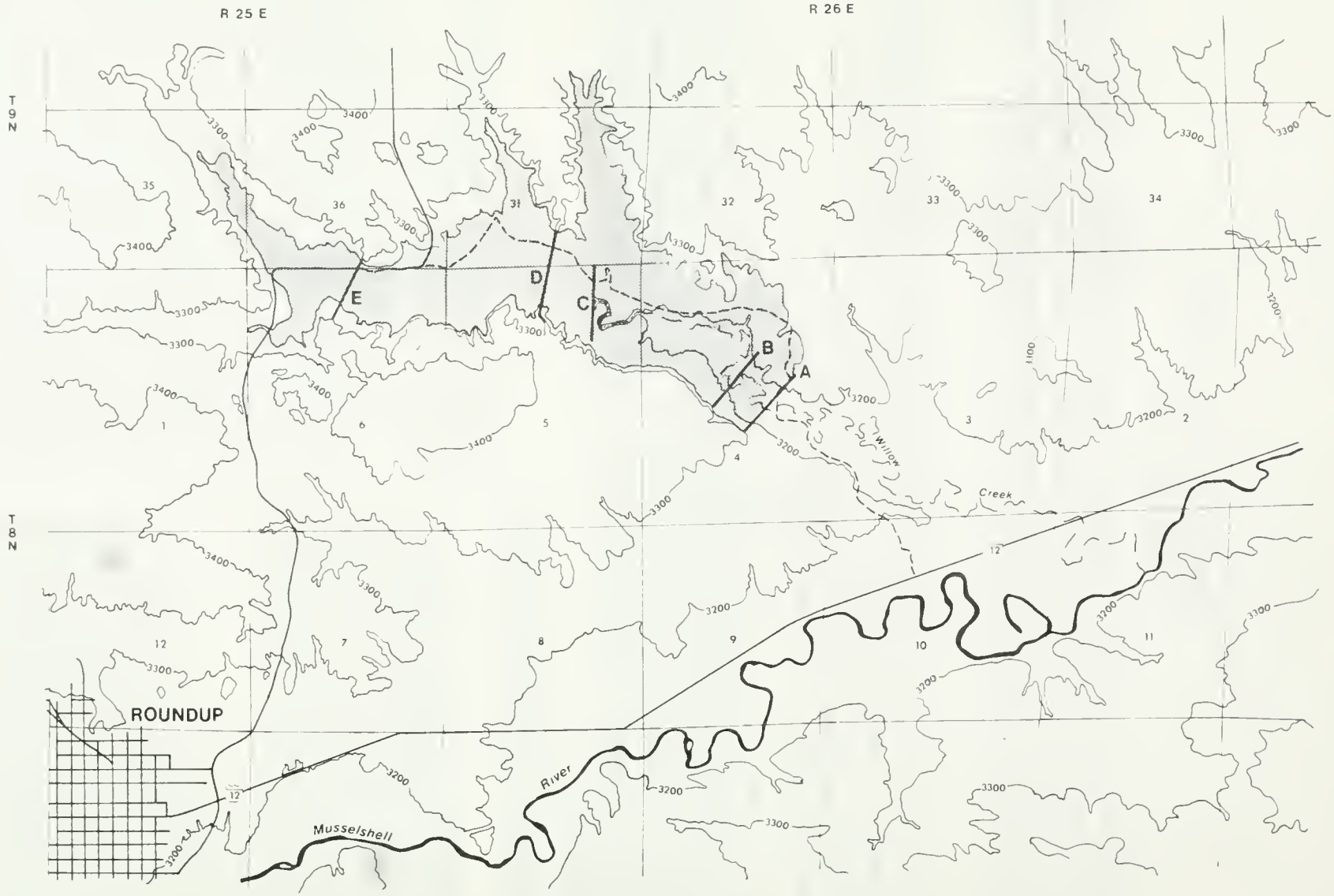


TABLE 1
WILLOW CREEK SITE A COMBINATIONS AND WOMAN'S POCKET SITE COST SUMMARY

Combination			Total Project Cost	Annual Costs					Annual Cost Per Acre-Foot
Storage Capacity (Acre-Feet)	Number of Pumps	Firm Annual Yield (Acre-Feet/Yr.)		Project n = 40 i = 6 5/8 %	Power	Operation	Maintenance	Total n = 40 i = 6 5/8 %	
WILLOW CREEK SITE A									
30,000	5	10,000	$7,367,100	$528,700	$21,840	$ 9,020	$6,060	$565,620	$56.56
30,000	10	12,000	7,498,900	538,160	25,900	9,020	6,560	579,640	48.30
25,000	5	10,000	6,531,900	468,760	20,180	8,810	5,810	503,560	50.36
25,000	13	11,000	6,683,300	479,630	22,130	8,830	6,080	516,670	46.97
20,000	5	9,000	5,841,100	419,200	17,410	8,640	5,360	450,610	50.07
20,000	10	10,000	5,923,200	425,080	19,220	8,640	5,610	458,550	45.86
15,000	3	7,000	4,407,800	316,330	12,380	8,290	4,440	341,440	48.78
15,000*	7	8,000	4,473,500	321,040	14,200	8,360	4,780	348,380	43.55
10,000	2	5,000	3,318,300	238,140	8,110	7,990	3,580	257,820	51.56
10,000	4	6,000	3,347,100	240,220	9,660	7,990	3,870	261,720	43.62
WOMAN'S POCKET SITE									
30,000	10	12,000	$6,880,600	$493,790	$49,780	$10,620	$8,570	$562,760	$46.90

* Figure 2

and subtracting out evaporation and an assumed firm annual yield, it was possible to force all shortages to zero and determine the actual firm annual yield. Since the pumping season is off-season from normal irrigation and since flows between increments of pump capacities would allow some flows past the diversion, it was decided not to adjust the stream gage records by prior water rights although some exist. To simplify calculations, evaporation was the only water loss subtracted from reservoir operation; no deliver losses, seepage losses, side channel inflows, or return flows were accounted for. Although no instream flow requirement was guaranteed in this study, it is acknowledged that it may be required and not doing so may have a detrimental environmental effect. All of the above actions tend to over-estimate the water supply available and were taken because of the complexity of an accurate determination and also because it was felt that the results would still give the correct conclusion about the project. The firm annual yields for some of the combinations studied are listed in Table 1. The ones not included were left out because they did not increase the firm annual yield even though more pumps were added.

Cost Estimation

Direct field cost was separated into five major categories for estimation: dam structure, pumping plant, discharge line, diversion structure, and sump. The summation of these categories, plus contingencies and engineering services resulted in the total project cost. An itemized cost summary for the least-cost combination at site A is shown in Figure 2. For all other combinations, see appendix C. All costs are in 1977 dollars.

Dam Structure. The total dam structure cost includes the cost for a completed dam and for land acquisition. The unit cost of $2.50 per cubic yard of above-ground fill for a completed dam was determined by examining the unit cost for similar projects and comparing with the unit cost used by other agencies. The acreage that would have to be acquired for construction was estimated to equal 110 percent of the surface area of the reservoir. It was estimated from conversations with local landowners that a fair market value for the acreage would be $150 per acre. The total dam structure cost for the least-cost combination is $1,796,000.

Pump Plant. The cost curves used to estimate the cost of a pumping plant for the project were based on actual construction costs for projects constructed by the Bureau of Reclamation. The total pumping plant cost is a summation of the following component costs: pumps and prime movers, structures and improvement, accessory electrical equipment, switchyard, outlet manifold, and miscellaneous equipment. The cost curves had a base year of 1968 and were updated to January 1977 by use of the Bureau's cost indices. The component costs for the least-cost combination totaled $600,300.

Discharge Line. The discharge line costs were separated into pipe, excavation, and backfill. It was assumed reinforced concrete pipe would be used since steel pipe prices are slightly higher. Current prices for the pipe were obtained from the Bureau of Reclamation. Trench excavation costs were estimated at $3.75 per cubic yard. Compacted backfill was placed to a depth of the pipe diameter plus one foot at $10.00 per cubic yard; the remaining loose backfill was placed at $2.00 per cubic yard. The total discharge line cost is $599,400.

Diversion Structure. It was assumed that a diversion structure equivalent to the one on the Musselshell River at the inlet to Deadman's Basin supply canal would be adequate for this project. Current unit prices were applied to the quantities of material in that diversion to arrive at a total cost. The following unit prices were used: concrete at $300.00 per cubic yard, steel at $0.40 per pound, wet excavation at $3.75 per cubic yard, compacted backfill at $10.00 per cubic yard, and riprap at $15.00 per cubic yard. A diversion structure cost of $91,800 was estimated for all combinations.

Sump. The amounts of concrete and of excavation required for the sump varied with the number of pumps being used. Unit costs were estimated at $350.00 per cubic yard for concrete (price difference due to complexity of framing, strength of concrete, etc.) and $1.00 per cubic yard for dry mass excavation. With seven pumps, the costs are $20,200 for concrete and $4,300 for excavation,for a total sump cost of $24,500.

Contingencies and Engineering Services. Project contingencies were estimated at twenty-five percent of total direct field costs. In addition, it was estimated that engineering, final design, inspection, and other engineering services would amount to fifteen percent of total direct field costs. Contingencies and engineering services for the least-cost combination were estimated at $778,000 and $583,500 respectively.

Annual Costs

The annual costs for the project consist of annual equivalent project cost, electricity, operation, and maintenance. The annual equivalent project cost is the total project cost amortized for forty years at 6 5/8 percent interest which is the Water Resources Council standard.

Electricity costs were calculated from Montana Power Company's June, 1977 general service rate schedule; the pumping season, from October 1 to March 31, would not qualify for the irrigation rate schedule. The total electrical cost consists of a demand charge and a service charge based on the power required to pump the firm annual yield and the total kilowatt demand required when all pumps are operating.

Annual operation and maintenance costs were calculated from cost curves supplied by the Bureau of Reclamation. These curves are based on a study of 174 pumping plants ranging in size from 5 to 15,000 horsepower.

Operation cost includes costs for starting and stopping pumping units, opening and closing valves, observing and recording motor and pump performances, noting water levels and general operating conditions, routine cleaning, lubricating machinery, servicing plant facilities, and checking control equipment. Those factors affecting operation costs most are discharge, total head, length of operating season, and required attendance rate. It was assumed that this plant could be operated with an average daily attendance of 2.5 to 16 man-hours (semiattended) during the operating season.

Maintenance cost includes costs for periodic inspection and testing of equipment, dismantling pumps for inspection, repair or replacement of parts, cleaning and repair of motors, and repair of auxiliary and control equipment. This cost is dependent on discharge, total head, and storage capacity.

Totaling the annual costs for power, operation, and maintenance plus the annual equivalent project cost results in the total annual project cost. Annual cost calculations for the least-cost combination can be found in Figure 2; for all other combinations, see appendix C.

EVALUATION OF THE WOMAN'S POCKET (DRY LAKE) SITE

Location

The proposed Woman's Pocket project is about four miles northwest of Lavina in Township 7 North, Range 22 East, Section 27 (see figure 3). This site, a natural lake, has no regular outflow and would require extensive excavation for an outlet. Data for this site was available from previous investigations by the U.S. Bureau of Reclamation (USBR) and the DNRC.

Method of Evaluation

Excavation and storage capacity calculations were based on measurements taken from preliminary topography maps developed by the USBR; a 25-foot dam would provide 100,000 acre-feet of storage and only a small dike would be required to provide 30,000 acre-feet. Because of the relatively flat topography behind the dam, mud flats and blowing dust problems might develop.

Cost Estimation

The costs for this site, with the exception of outlet excavation, were calculated by the same criteria used for the Willow Creek sites. Because there would be a considerable amount of excavation required for an outlet, a cost for this was added. An itemized cost estimate for this site can be found in appendix C. Based on the USBR maps, an estimated 508,578 cubic yards of dry mass excavation at $1.00 per cubic yard would be required.

COST COMPARISON

A tabulation of the costs for the Willow Creek and Woman's Pocket sites may be found in Table 1. This table lists storage capacities, firm annual yields, numbers of pumps, total project costs, and annual project, operation, and total costs. Also listed is an estimated cost per acre-foot of water stored. The annual cost per acre-foot for the Woman's Pocket site ($46.90) compares closely to that for the least-cost combination at Willow Creek ($43.55). The differences in annual cost per acre foot is small enough to be insignificant.

ECONOMIC FEASIBILITY

Farm budgets were estimated, using data from the agricultural extension service, the Bureau of Reclamation, and local farmers to evaluate potential users' ability to pay for water from the study

FIGURE 2. WILLOW CREEK SITE A

STORAGE: 15,000 AF FIRM ANNUAL YIELD: 8,000 AF/YR NUMBER OF PUMPS: 7

Discharge: 6.25 cfs/pump Total Head: 145 ft
Discharge Length: 6,600 ft Diameter: 45 in
Surface Area of Reservoir: 580 ac
T = 26 weeks I = 1.71 Wo = $5.50
Semiattended Plant Wm = $6.00
January 1977 Prices

PROJECT COSTS

	Unit	Quantity	Unit Cost	Rounded Total Cost
Dam Structure				
Complete Structure	CY	680,000	$ 2.50	$1,700,000
Land Rights	AC	640	150.00	96,000
SUBTOTAL				$1,796,000
Pumping Plant				
Pumps and Prime Movers				$ 119,800
Structures and Improvements				214,200
Accessory Electrical Equipment				103,400
Miscellaneous Equipment				13,000
Switchyard 69KV 731 KVA				90,000
Outlet Manifold				59,900
SUBTOTAL				$ 600,300
Discharge Line				
Reinforced Concrete Pipe	FT	6,600	67.00	$ 442,200
Excavation	CY	17,875	3.75	67,000
Backfill				
Class A	CY	6,910	10.00	69,100
Class C	CY	10,540	2.00	21,100
SUBTOTAL				$ 599,400

Diversion Structure				
Concrete	CY	250	3.00	$ 75,000
Steel	LBS	20,000	0.40	8,000
Excavation	CY	1,400	3.75	5,200
Backfill	CY	300	10.00	3,000
Riprap	CY	40	15.00	600
SUBTOTAL				$ 91,800
Sump				
Concrete	CY	58	350.00	$ 20,200
Excavation	CY	4,300	1.00	4,300
SUBTOTAL				$ 24,500
Total Direct Field Costs				$3,112,000
Contingencies	25%			778,000
Engineering	15%			583,500
TOTAL PROJECT COST				$4,473,500

ANNUAL COSTS

Operation Costs

$$Co = 5.2\ Q^{0.05}\ H^{0.25}\ T\ (2.5\ Wo + I)$$ 8,360

Maintenance Cost

$$Cm = 2.0\ Q^{0.11}\ H^{0.41}\ G^{0.43}\ (0.49\ Wm + I)$$ 4,780

Electrical Costs

$CE_d = (7)\ (100)\ (.746)\ (1.32) = 689$ 14,200

$CE_s = (8{,}000/2805)\ (100)\ (4724.52)\ (0.01) = 13{,}475$

ANNUAL PROJECT COSTS

Annual Equivalent Project Cost (40 years at 6 5/8%)	$ 321,040
Operation	8,360
Maintenance and Replacement	4,780
Electricity	14,200
TOTAL ANNUAL PROJECT COST	$ 348,380

reservoirs. It was assumed for this analysis that full on-farm water supplies would be used, even though some of the water would be used to supplement partial irrigation on some lands.

Crops and Irrigation Systems

The three main crops grown in the area are alfalfa hay, corn silage, and small grains. Most are irrigated by sprinkler or flood irrigation systems.

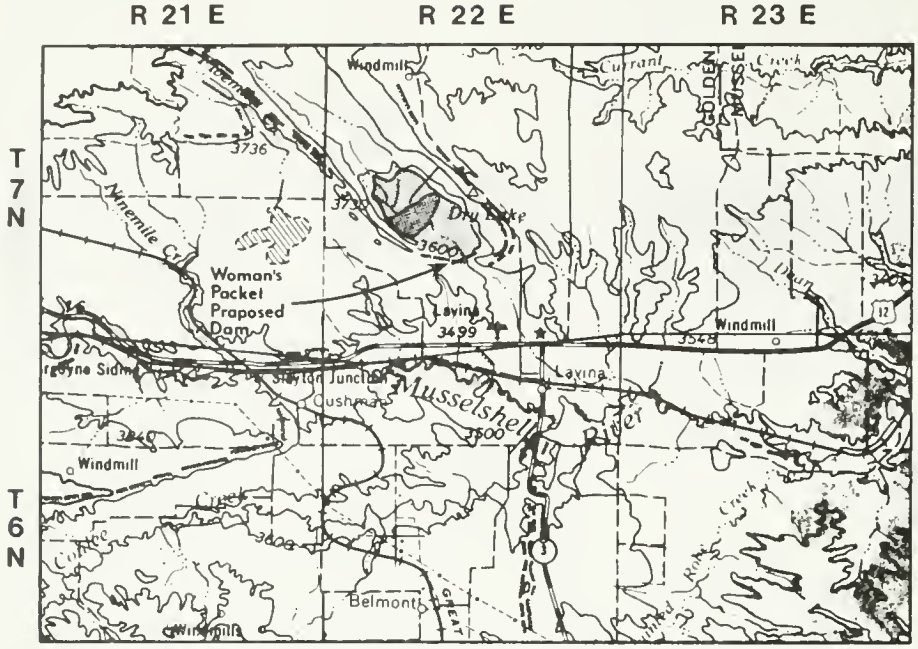


FIGURE 3. LOCATION OF WOMAN'S POCKET (DRY LAKE) SITE

About 80 percent of the proposed project water would be used to irrigate alfalfa with corn and small grains equally sharing the remaining 20 percent. Sprinkler irrigation systems would be used to apply 25 percent of the water and flood systems would be used to apply 75 percent. Based on a weighted average irrigation requirement, all (100 percent) of the corn and small grains water would be applied through sprinklers while only 7 percent of the alfalfa allocation would be. The remaining 93 percent of the alfalfa water allocation would be used for flooding. The above percentages of various crops grown and irrigation systems used were based on information contained in USBR studies and conversations with local residents.

TABLE 2 CROP WATER REQUIREMENTS

Crop	Total Consumptive Use (inches)	Effective Rainfall (inches)	Net Irrigation Requirement (inches)	Farm Delivery (Ac-Ft/Ac)	Average Delivery Requirement (Ac-Ft/Ac)
Alfalfa	28.99	6.85	22.14		3.1
Sprinkler				2.6	
Flood				3.1	
Corn, Silage	20.78	5.44	15.34		2.0
Sprinkler				1.8	
Flood				2.1	
Grain	18.46	5.62	12.84		1.7
Sprinkler				1.5	
Flood				1.8	

NOTE:Net irrigation requirement is the water in addition to natural precipitation which needs to be supplied by the proposed irrigation system.

Crop Water Requirements

The water requirements for the project were estimated from the Soil Conservation Service's **Irrigation Guide for Montana.** Table 2 lists the crop water requirements for the three cropping patterns. The average delivery requirement is a weighted average based on 25 percent sprinkler and 75 percent flood irrigation.

Farm Budgets

Table 3 shows the farm budgets on a per-acre basis. As is evident, the water costs make either site economically unfeasible. (Note that the pumping and irrigation costs are an averaged weighted cost between 25 percent sprinkler and 75 percent flood irrigation). January, 1978 prices were used to make the calculations, using yields estimates of 4.5 ton hay/acre, 20 ton corn/acre and 80 bu small grain/acre from the Bureau of Reclamation and Cooperative Extension Service.

An average pumping pressure head of 125 feet was used to determine sprinkler irrigation power requirements. The costs of pumping water into flood irrigation systems was assumed negligible since the average lift (from river to ditch) was estimated at ten feet, resulting in underestimation of the costs to the ranches.

TABLE 3
FARM BUDGETS (PER ACRE)

ITEM	PER ACRE COST		
Crop	Alfalfa Hay	Corn Silage	Small Grain
On Farm Costs	$192.14	$266.20	$221.87
Pumping Costs	2.63	8.40	8.40
Irrigation System	7.93	44.02	25.58
Total Production Cost	202.70	318.62	255.85
Revenue From Sale	4.5T @ $50 = $225.00	20T @ $14 = $280.00	80 bu. @ $2.50 = $200.00
Water Costs Payment Ability (per acre)	22.20	– 38.62	– 55.85
Willow Creek Actual Water Costs ($43.56 per acre-foot)	× 3.1 ac-ft = $135.04	× 1.8 ac-ft = 78.41	× 1.5 ac-ft = 65.34
Woman's Pocket Actual Water Costs ($46.90 per acre-foot)	× 3.1 ac-ft = $145.39	× 1.8 ac-ft = 84.42	× 1.5 ac-ft = 70.35

OTHER CONSIDERATIONS

If the project is carried further than this prefeasibility study, other investigations will have to be undertaken. For instance, environmental impacts were not assessed due to the conclusions that were reached. There could be a detrimental effect on fisheries if the project was constructed as assumed in this report. There were also no geological investigations done at any of the sites. These should definitely be completed if there is any further study done on the project. The estimated costs included in this report are in 1977 dollars; if further study is conducted at a later date, the cost will have to be adjusted accordingly.

CONCLUSIONS AND RECOMMENDATIONS

The costs of water from either the Willow Creek or Woman's Pocket sites are economically prohibitive at this time. At some future date, the revenue from agricultural commodities may be such that these locations may warrant a second feasibility appraisal. DNRC will maintain a file on the information used in this prefeasibility report which will be available to interested parties.

Appendix A

Technical Assistance Request

COPY of Original Letter

P.O. Box 601
Roundup, MT 59072
4 May 1977

Dept. Natural Resources & Conservation
Attn: Technical Assistance Program
Helena, Montana 59601

Gentlemen:

Members of the Water Resources Division attended a meeting here in Roundup on May 2 with the Musselshell River Water Development Association. They explained that your services are available to assist with the conduct of preliminary studies on the feasibility of potential water storage sites.

This letter will serve as the MRWDA's request for such assistance on two sites discussed at that meeting - the Willow Creek Site and the Dry Lake (Woman's Pocket) Site.

Our association is prepared to provide whatever assistance you may require in making these studies at the earliest possible date. Additional information may be had by contacting:

J. K. Kuzara
P. O. Box 601
Roundup, MT 59072
323-1303 office
323-2628 home

Don Belcher
1116 2nd St W
Roundup, MT 59072
323-1610 office
323-1152 home

Your attention to this matter will be greatly appreciated. With best regards, I remain

Sincerely,

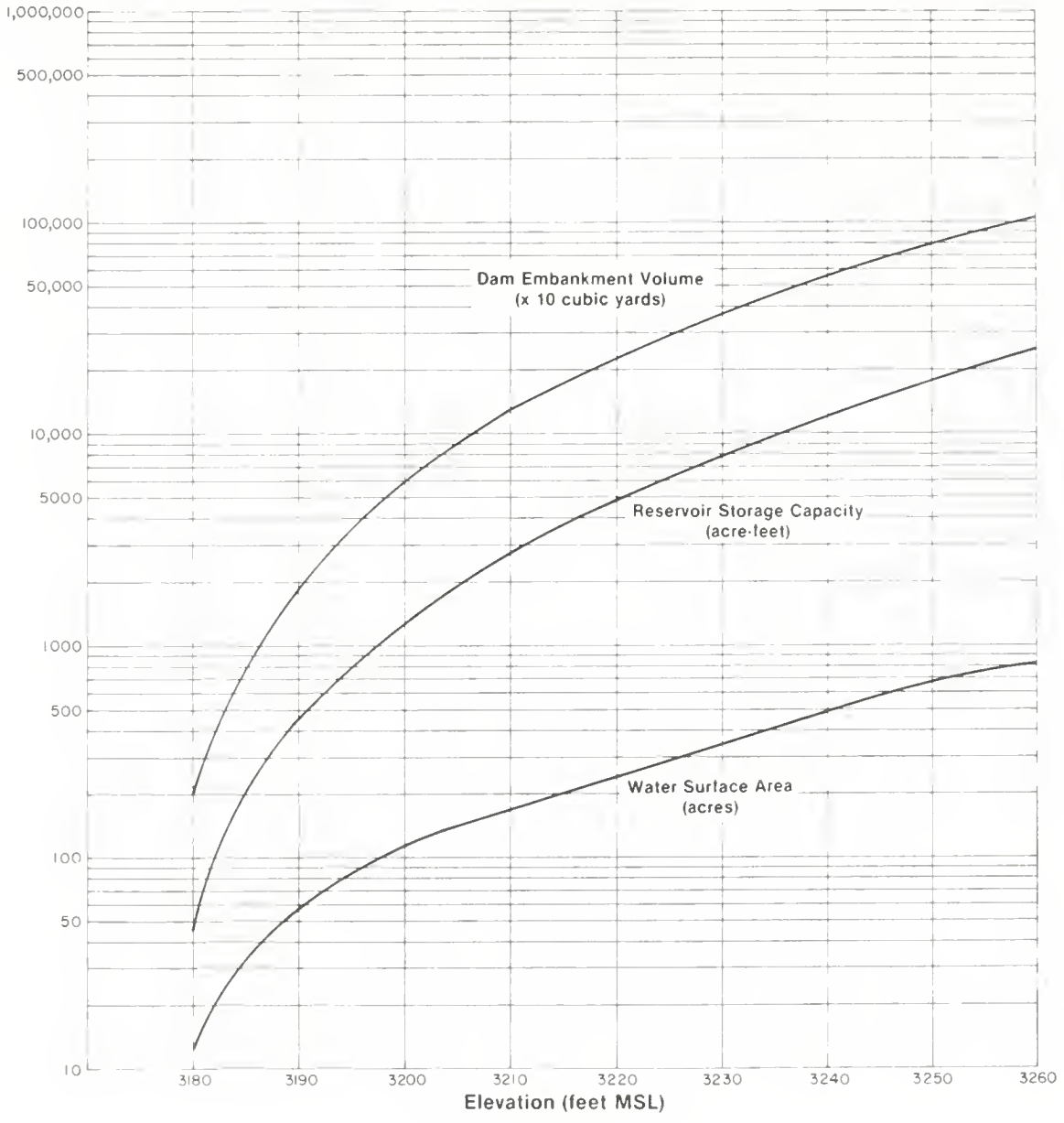
J. K. KUZARA, Secretary-Treasurer
Musselshell River Water Development Assoc.

Appendix B

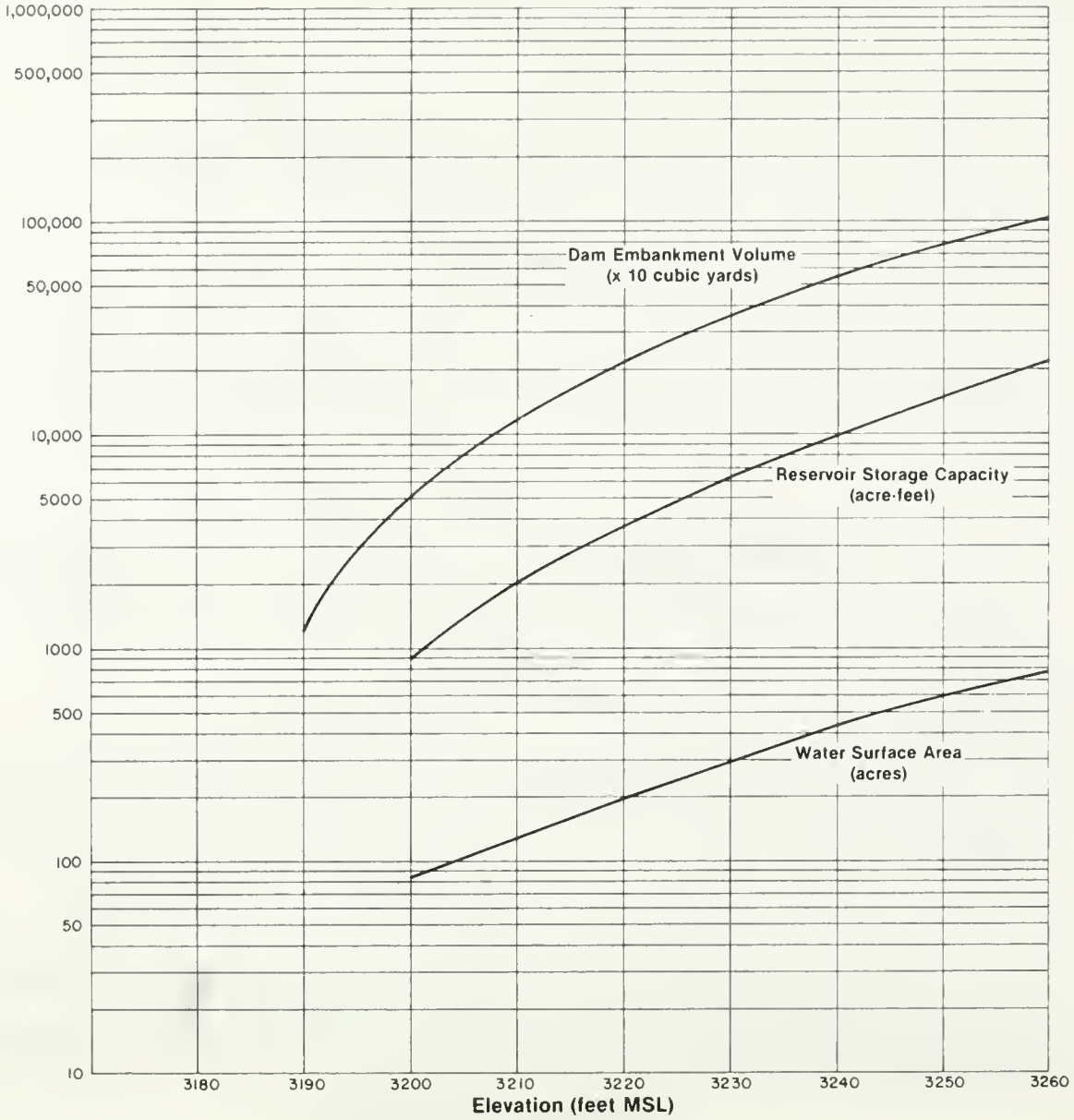
Stage-Storage-Embankment Curves

Willow Creek Sites A through E

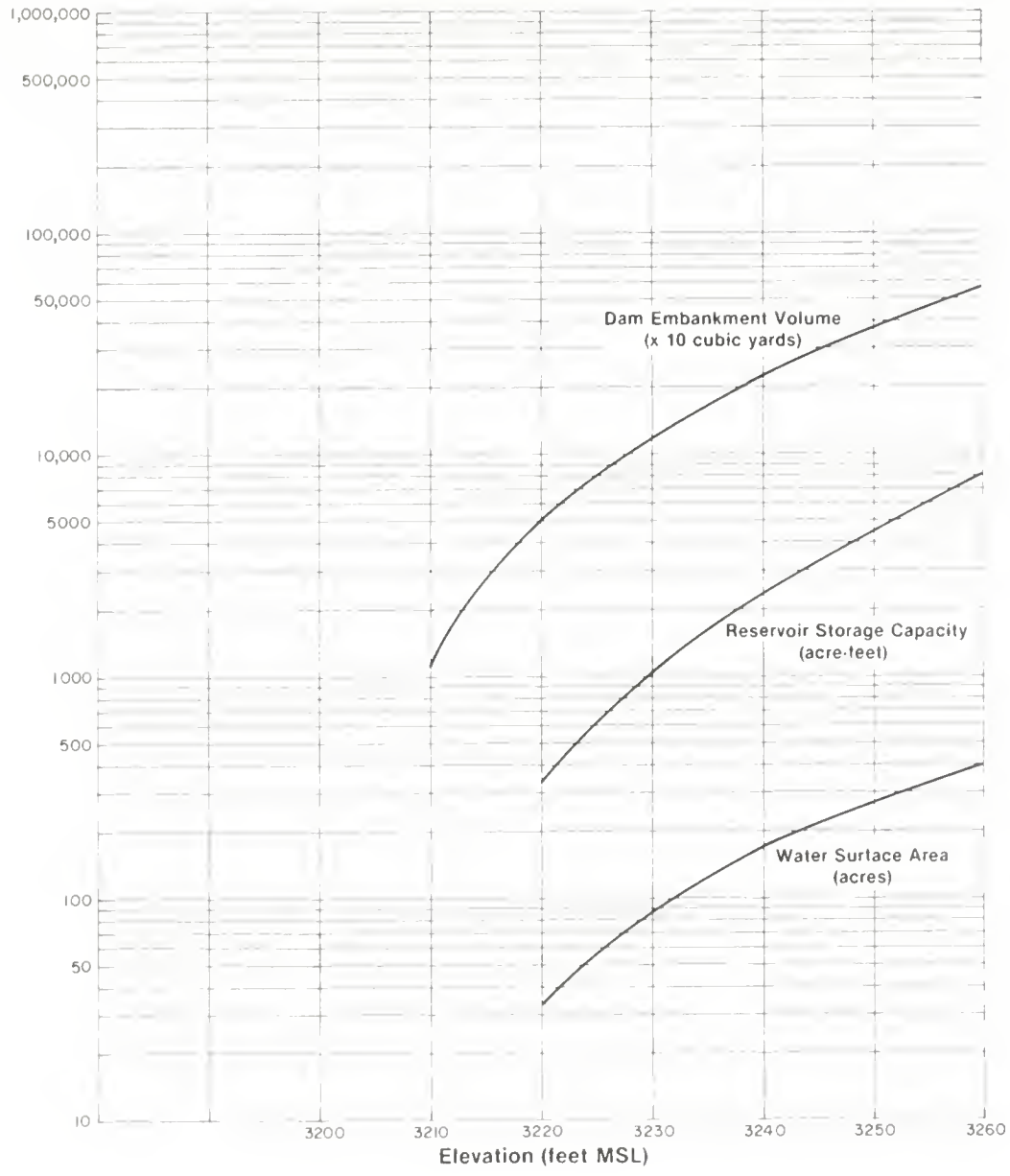
WILLOW CREEK SITE A



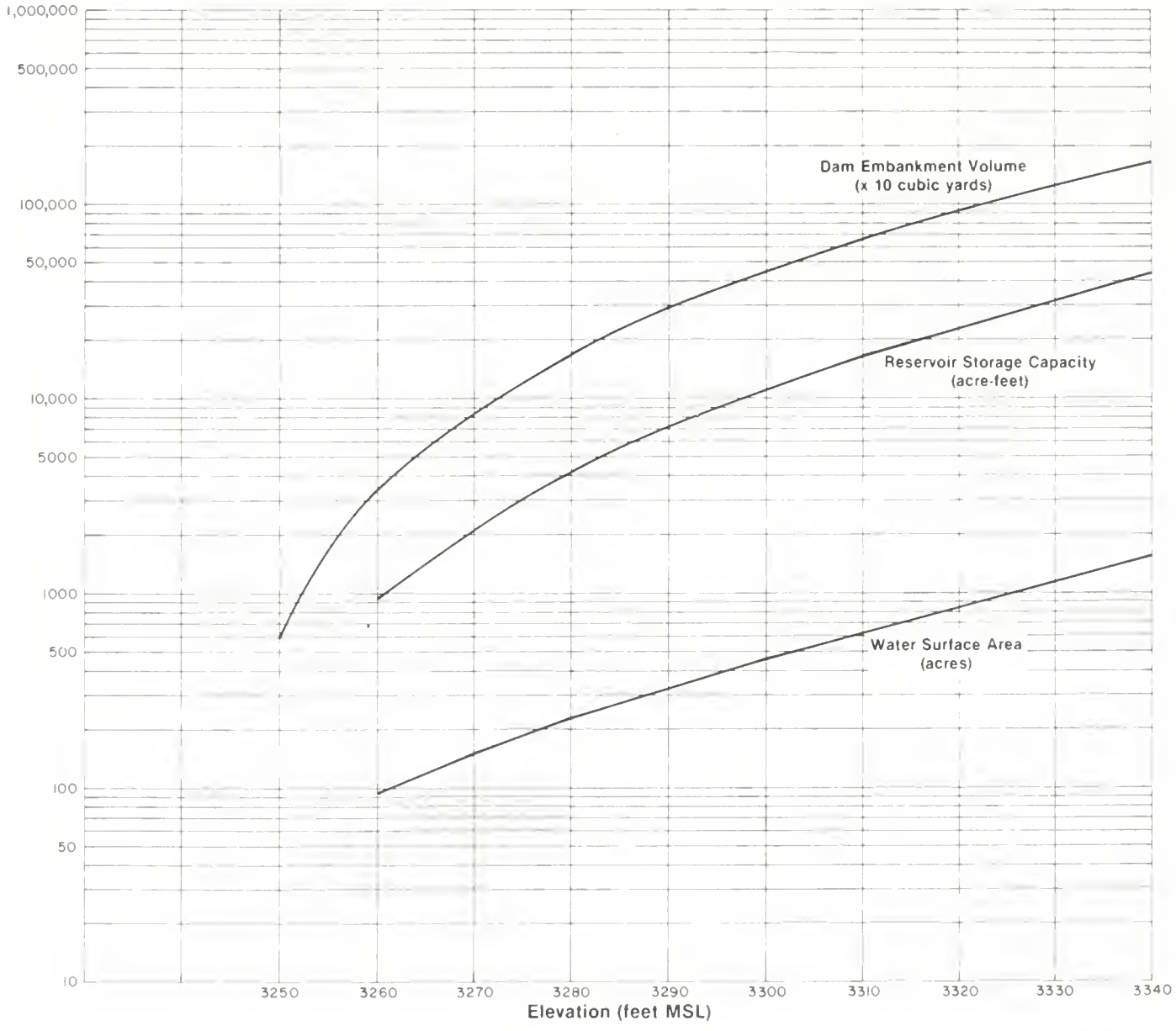
WILLOW CREEK SITE B



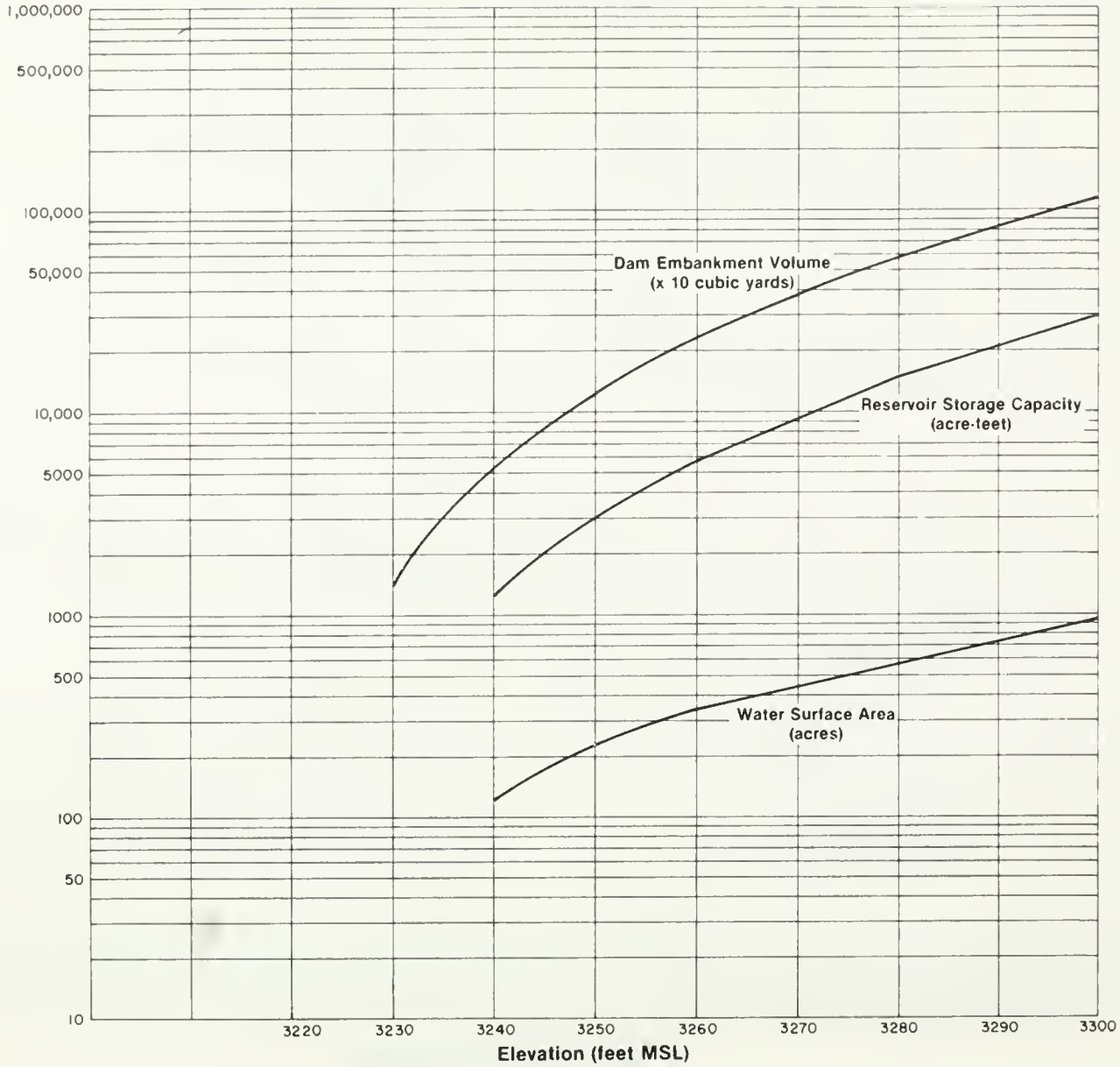
WILLOW CREEK SITE C



WILLOW CREEK SITE E



WILLOW CREEK SITE D



Appendix C

Itemized Cost Summaries:

Willow Creek Site A Combinations

and

Woman's Pocket Site

WOMAN'S POCKET (DRY LAKE) SITE

STORAGE: 30,000 AF FIRM ANNUAL YIELD: 12,000 AF/YR NUMBER OF PUMPS: 10

Discharge: 7.8 cfs/pump Total Head: 279 ft
Discharge Length: 15,800 ft Diameter: 48 in
Surface Area of Reservoir: 1440 ac
T = 26 weeks I = 1.71 Wo = $5.50
Semiattended Plant Wm = $6.00
January 1977 Prices

PROJECT COSTS

	Unit	Quantity	Unit Cost	Rounded Total Cost
Dam Structure				
Complete Structure	CY	5,300	$ 2.50	$ 13,200
Land Rights	AC	1,600	150.00	240,000
SUBTOTAL				$ 253,200
Pumping Plant				
Pumps and Prime Movers				$ 414,700
Structures and Improvements				713,900
Accessory Electrical Equipment				527,300
Miscellaneous Equipment				34,100
Switchyard 69KV 731 KVA				132,000
Outlet Manifold				207,400
SUBTOTAL				$2,029,400
Discharge Line				
Reinforced Concrete Pipe	FT	15,800	92.00	$1,453,600
Excavation	CY	46,800	3.75	175,500
Backfill				
Class A	CY	18,460	10.00	184,600
Class C	CY	26,900	2.00	53,800
SUBTOTAL				$1,867,500
Diversion Structure				
Concrete	CY	250	3.00	$ 75,000
Steel	LBS	20,000	0.40	8,000
Excavation	CY	1,400	3.75	5,200
Backfill	CY	300	10.00	3,000
Riprap	CY	40	15.00	600
SUBTOTAL				$ 91,800

Sump				
Concrete	CY	86	350.00	$ 30,100
Excavation	CY	5,900	1.00	5,900
SUBTOTAL				$ 36,000
Outlet				
Excavation	CY	508,600	1.00	$ 508,600
SUBTOTAL				$ 508,600
Total Direct Field Costs				$4,786,500
Contingencies	25%			1,196,600
Engineering	15%			897,500
TOTAL PROJECT COST				$6,880,600

ANNUAL COSTS

Operation Costs	
$Co = 5.2\ Q^{0.05}\ H^{0.25}\ T\ (2.5\ Wo + I)$	10,620
Maintenance Cost	
$Cm = 2.0\ Q^{0.11}\ H^{0.41}\ G^{0.43}\ (0.49\ Wm + I)$	8,570
Electrical Costs	
$CE_d = (10)\ (288)\ (0.746)\ (1.32) = 2836$	49,780
$CE_s = (12{,}000/3478.2)\ (288)\ (4724.52)\ (0.01) =$ **46,944**	

ANNUAL PROJECT COSTS

Annual Equivalent Project Cost (40 years at 6 5/8%)	$ 493,790
Operation	10,620
Maintenance and Replacement	8,570
Electricity	49,780
TOTAL ANNUAL PROJECT COST	$ 562,760

WILLOW CREEK SITE A

STORAGE: 30,000 AF FIRM ANNUAL YIELD: 10,000 AF/YR NUMBER OF PUMPS: 5

Discharge: 15.5 cfs/pump Total Head: 145 ft
Discharge Length: 6,600 ft Diameter: 48 in
Surface Area of Reservoir: 920 ac
T = 26 weeks I = 1.71 Wo = $5.50
Semiattended Plant Wm = $6.00
January 1977 Prices

PROJECT COSTS

	Unit	Quantity	Unit Cost	Rounded Total Cost
Dam Structure				
Complete Structure	CY	1,200,000	$ 2.50	$3,000,000
Land Rights	AC	1,000	150.00	150,000
SUBTOTAL				$3,150,000
Pumping Plant				
Pumps and Prime Movers				$ 275,900
Structures and Improvements				479,300
Accessory Electrical Equipment				148,200
Miscellaneous Equipment				24,800
Switchyard 69KV 731 KVA				110,000
Outlet Manifold				138,000
SUBTOTAL				$1,176,200
Discharge Line				
Reinforced Concrete Pipe	LF	6,600	69.00	$ 514,800
Excavation	CY	19,555	3.75	73,300
Backfill				
Class A	CY	7,710	10.00	77,100
Class C	CY	11,240	2.00	22,500
SUBTOTAL				$ 687,700

Diversion Structure				
Concrete	CY	250	3.00	$ 75,000
Steel	LBS	20,000	0.40	8,000
Excavation	CY	1,400	3.75	5,200
Backfill	CY	300	10.00	3,000
Riprap	CY	40	15.00	600
SUBTOTAL				$ 91,800
Sump				
Concrete	CY	45	350.00	$ 15,800
Excavation	CY	4,300	1.00	4,300
SUBTOTAL				$ 24,500
Total Direct Field Costs				$3,112,000
Contingencies	25%			778,000
Engineering	15%			583,500
TOTAL PROJECT COST				$4,473,500

ANNUAL COSTS

Operation Costs $Co = 5.2\ Q^{0.05}\ H^{0.25}\ T\ (2.5\ Wo + I)$	9,020
Maintenance Cost $Cm = 2.0\ Q^{0.11}\ H^{0.41}\ G^{0.43}\ (0.49\ Wm + I)$	6,060
Electrical Costs	
$CE_d = (5)\ (300)\ (.746)\ (1.32) = 1480$	21,840
$CE_s = (10{,}000/6960)\ (300)\ (4724.52)\ (0.01)$	20,360

ANNUAL PROJECT COSTS

Annual Equivalent Project Cost (40 years at 6 5/8%)	$ 321,040
Operation	9,020
Maintenance and Replacement	6,060
Electricity	21,840
TOTAL ANNUAL PROJECT COST	$ 348,380

WILLOW CREEK SITE A

STORAGE: 30,000 AF FIRM ANNUAL YIELD: 12,000 AF/YR NUMBER OF PUMPS: 10

Discharge: 7.8 cfs/pump Total Head: 145 ft
Discharge Length: 6,600 ft Diameter: 48 in
Surface Area of Reservoir: 920 ac
T = 26 weeks I = 1.71 Wo = $5.50
Semiattended Plant Wm = $6.00
January 1977 Prices

PROJECT COSTS

	Unit	Quantity	Unit Cost	Rounded Total Cost
Dam Structure				
Complete Structure	CY	1,200,000	$ 2.50	$3,000,000
Land Rights	AC	1,000	150.00	150,000
SUBTOTAL				$3,150,000
Pumping Plant				
Pumps and Prime Movers				$ 275,900
Structures and Improvements				479,300
Accessory Electrical Equipment				203,300
Miscellaneous Equipment				24,800
Switchyard 69KV 731 KVA				110,000
Outlet Manifold				138,000
SUBTOTAL				$1,176,200
Discharge Line				
Reinforced Concrete Pipe	LF	6,600	69.00	$ 514,800
Excavation	CY	19,555	3.75	73,300
Backfill				
Class A	CY	7,710	10.00	77,100
Class C	CY	11,240	2.00	22,500
SUBTOTAL				$ 687,700

Diversion Structure				
Concrete	CY	250	3.00	$ 75,000
Steel	LBS	20,000	0.40	8,000
Excavation	CY	1,400	3.75	5,200
Backfill	CY	300	10.00	3,000
Riprap	CY	40	15.00	600
SUBTOTAL				$ 91,800
Sump				
Concrete	CY	86	350.00	$ 30,100
Excavation	CY	5,900	1.00	5,900
SUBTOTAL				$ 36,000
Total Direct Field Costs				$5,216,600
Contingencies	25%			1,304,200
Engineering	15%			978,100
TOTAL PROJECT COST				$7,498,900

ANNUAL COSTS

Operation Costs

$$Co = 5.2\ Q^{0.05}\ H^{0.25}\ T\ (2.5\ Wo + I)$$ 9,020

Maintenance Cost

$$Cm = 2.0\ Q^{0.11}\ H^{0.41}\ G^{0.43}\ (0.49\ Wm + I)$$ 6,560

Electrical Costs

$CE_d = (10)\ (150)\ (.746)\ (1.32) = 1480$
$CE_S = (12{,}000/3480)\ (150)\ (4724.52)\ (0.01) = 24{,}440$

ANNUAL PROJECT COSTS

Annual Equivalent Project Cost (40 years at 6 5/8%)	$ 538,160
Operation	9,020
Maintenance and Replacement	6,560
Electricity	25,900
TOTAL ANNUAL PROJECT COST	$ 579,640

WILLOW CREEK SITE A

STORAGE: 25,000 AF FIRM ANNUAL YIELD: 10,000 AF/YR NUMBER OF PUMPS: 5

Discharge: 13.89 cfs/pump Total Head: 135 ft
Discharge Length: 6,600 ft Diameter: 48 in
Surface Area of Reservoir: 820 ac
T = 26 weeks I = 1.71 Wo = $5.50
Semiattended Plant Wm = $6.00
January 1977 Prices

PROJECT COSTS

	Unit	Quantity	Unit Cost	Rounded Total Cost
Dam Structure				
Complete Structure	CY	1,050,000	$ 2.50	$2,625,000
Land Rights	AC	900	150.00	135,000
SUBTOTAL				$2,760,000
Pumping Plant				
Pumps and Prime Movers				$ 225,000
Structures and Improvements				391,600
Accessory Electrical Equipment				131,000
Miscellaneous Equipment				21,100
Switchyard 69KV 731 KVA				104,000
Outlet Manifold				112,500
SUBTOTAL				$ 985,200
Discharge Line				
Reinforced Concrete Pipe	LF	6,600	69.00	$ 514,800
Excavation	CY	19,555	3.75	73,300
Backfill				
Class A	CY	7,710	10.00	77,100
Class C	CY	11,240	2.00	22,500
SUBTOTAL				$ 687,700

Diversion Structure				
Concrete	CY	250	3.00	$ 75,000
Steel	LBS	20,000	0.40	8,000
Excavation	CY	1,400	3.75	5,200
Backfill	CY	300	10.00	3,000
Riprap	CY	40	15.00	600
SUBTOTAL				$ 91,800
Sump				
Concrete	CY	45	350.00	$ 15,700
Excavation	CY	3,500	1.00	3,500
SUBTOTAL				$ 19,200
Total Direct Field Costs				$4,543,900
Contingencies	25%			1,136,000
Engineering	15%			852,000
TOTAL PROJECT COST				$6,531,900

ANNUAL COSTS

Operation Costs

$Co = 5.2\ Q^{0.05}\ H^{0.25}\ T\ (2.5\ Wo + I)$ 8,810

Maintenance Cost

$Cm = 2.0\ Q^{0.11}\ H^{0.41}\ G^{0.43}\ (0.49\ Wm + I)$ 5,810

Electrical Costs

$CE_d = (5)\ (250)\ (.746)\ (1.32) = 1230$ 20,180

$CE_s = (1{,}000/6233)\ (250)\ (4724.52)\ (0.01) = 18{,}950$

ANNUAL PROJECT COSTS

Annual Equivalent Project Cost (40 years at 6 5/8%)	$ 468,760
Operation	8,810
Maintenance and Replacement	5,810
Electricity	20,180
TOTAL ANNUAL PROJECT COST	$ 503,560

WILLOW CREEK SITE A

STORAGE: 25,000 AF FIRM ANNUAL YIELD: 11,000 AF/YR NUMBER OF PUMPS: 13

Discharge: 5.56 cfs/pump Total Head: 135 ft
Discharge Length: 6,600 ft Diameter: 48 in
Surface Area of Reservoir: 820 ac
T = 26 weeks I = 1.71 Wo = $5.50
Semiattended Plant Wm = $6.00
January 1977 Prices

PROJECT COSTS

	Unit	Quantity	Unit Cost	Rounded Total Cost
Dam Structure				
Complete Structure	CY	1,050,000	$ 2.50	$2,625,000
Land Rights	AC	900	150.00	135,000
SUBTOTAL				$2,760,000
Pumping Plant				
Pumps and Prime Movers				$ 225,000
Structures and Improvements				391,600
Accessory Electrical Equipment				209,600
Miscellaneous Equipment				21,100
Switchyard 69KV 731 KVA				104,000
Outlet Manifold				112,500
SUBTOTAL				$1,063,800
Discharge Line				
Reinforced Concrete Pipe	LF	6,600	69.00	$ 514,800
Excavation	CY	19,555	3.75	73,300
Backfill				
Class A	CY	7,710	10.00	77,100
Class C	CY	11,240	2.00	22,500
SUBTOTAL				$ 687,700

Diversion Structure				
Concrete	CY	250	3.00	$ 75,000
Steel	LBS	20,000	0.40	8,000
Excavation	CY	1,400	3.75	5,200
Backfill	CY	300	10.00	3,000
Riprap	CY	40	15.00	600
SUBTOTAL				$ 91,800
Sump				
Concrete	CY	110	350.00	$ 38,700
Excavation	CY	7,300	1.00	7,300
SUBTOTAL				$ 46,000
Total Direct Field Costs				$4,649,300
Contingencies	25%			1,162,300
Engineering	15%			871,700
TOTAL PROJECT COST				$6,683,300

ANNUAL COSTS

Operation Costs

$Co = 5.2\ Q^{0.05}\ H^{0.25}\ T\ (2.5\ Wo + I)$ 8,830

Maintenance Cost

$Cm = 2.0\ Q^{0.11}\ H^{0.41}\ G^{0.43}\ (0.49\ Wm + I)$ 6,080

Electrical Costs

$CE_d = (13)\ (100)\ (.746)\ (1.32) = 1280$

$CE_s = (11{,}000/2493)\ (100)\ (4724.52)\ (0.01) = 20{,}850$ 22,130

ANNUAL PROJECT COSTS

Annual Equivalent Project Cost (40 years at 6 5/8%)	$ 479,630
Operation	8,830
Maintenance and Replacement	6,080
Electricity	22,130
TOTAL ANNUAL PROJECT COST	$ 516,670

WILLOW CREEK SITE A

STORAGE: 20,000 AF FIRM ANNUAL YIELD: 9,000 AF/YR NUMBER OF PUMPS: 5

Discharge: 11.54 cfs/pump Total Head: 130 ft
Discharge Length: 6,600 ft Diameter: 45 in
Surface Area of Reservoir: 820 ac
T = 26 weeks I = 1.71 Wo = $5.50
Semiattended Plant Wm = $6.00
January 1977 Prices

PROJECT COSTS

	Unit	Quantity	Unit Cost	Rounded Total Cost
Dam Structure				
Complete Structure	CY	870,000	$ 2.50	$2,175,000
Land Rights	AC	790	150.00	118,500
SUBTOTAL				$2,293,500
Pumping Plant				
Pumps and Prime Movers				$ 194,700
Structures and Improvements				346,700
Accessory Electrical Equipment				113,700
Miscellaneous Equipment				188,200
Switchyard 69KV 731 KVA				100,000
Outlet Manifold				97,400
SUBTOTAL				$ 991,100
Discharge Line				
Reinforced Concrete Pipe	FT	6,600	70.00	$ 462,000
Excavation	CY	17,875	3.75	67,000
Backfill				
Class A	CY	6,910	10.00	69,100
Class C	CY	10,540	2.00	21,100
SUBTOTAL				$ 619,200

Diversion Structure				
Concrete	CY	250	3.00	$ 75,000
Steel	LBS	20,000	0.40	8,000
Excavation	CY	1,400	3.75	5,200
Backfill	CY	300	10.00	3,000
Riprap	CY	40	15.00	600
SUBTOTAL				$ 91,800
Sump				
Concrete	CY	42	350.00	$ 14,800
Excavation	CY	3,400		3,400
SUBTOTAL				$ 18,200
Total Direct Field Costs				$4,063,400
Contingencies	25%			1,015,800
Engineering	15%			761,900
TOTAL PROJECT COST				$5,841,100

ANNUAL COSTS

Operation Costs

$Cc = 5.2\ Q^{0.05}\ H^{0.25}\ T\ (2.5\ Wo + I)$ 8,640

Maintenance Cost

$Cm = 2.0\ Q^{0.11}\ H^{0.41}\ G^{0.43}\ (0.49\ Wm + I)$ 5,360

Electrical Costs

$CE_d = (5)\ (200)\ (.746)\ (1.32) = 985$
$CE_s = (9{,}000/5178)\ (200)\ (4724.52)\ (0.01) = 16{,}424$ 17,410

ANNUAL PROJECT COSTS

Annual Equivalent Project Cost (40 years at 6 5/8%)	$ 419,200
Operation	8,640
Maintenance and Replacement	5,360
Electricity	17,410
TOTAL ANNUAL PROJECT COST	$ 450,610

WILLOW CREEK SITE A

STORAGE: 20,000 AF FIRM ANNUAL YIELD: 10,000 AF/YR NUMBER OF PUMPS: 10

Discharge: 5.8 cfs/pump Total Head: 130 ft
Discharge Length: 6,600 ft Diameter: 45 in
Surface Area of Reservoir: 820 ac
T = 26 weeks I = 1.71 Wo = $5.50
Semiattended Plant Wm = $6.00
January 1977 Prices

PROJECT COSTS

	Unit	Quantity	Unit Cost	Rounded Total Cost
Dam Structure				
Complete Structure	CY	870,000	$ 2.50	$2,175,000
Land Rights	AC	790	150.00	118,500
SUBTOTAL				$2,293,500
Pumping Plant				
Pumps and Prime Movers				$ 194,700
Structures and Improvements				346,700
Accessory Electrical Equipment				155,100
Miscellaneous Equipment				188,200
Switchyard 69KV 731 KVA				100,000
Outlet Manifold				97,400
SUBTOTAL				$1,082,100
Discharge Line				
Reinforced Concrete Pipe	FT	6,600	70.00	$ 462,000
Excavation	CY	17,875	3.75	67,000
Backfill				
Class A	CY	6,910	10.00	69,100
Class C	CY	10,540	2.00	21,100
SUBTOTAL				$ 619,200

Diversion Structure				
Concrete	CY	250	3.00	$ 75,000
Steel	LBS	20,000	0.40	8,000
Excavation	CY	1,400	3.75	5,200
Backfill	CY	300	10.00	3,000
Riprap	CY	40	15.00	600
SUBTOTAL				$ 91,800
Sump				
Concrete	CY	81	350.00	$ 28,300
Excavation	CY	5,600	1.00	5,600
SUBTOTAL				$ 33,900
Total Direct Field Costs				$4,120,500
Contingencies	25%			1,030,100
Engineering	15%			772,600
TOTAL PROJECT COST				$5,923,200

ANNUAL COSTS

Operation Costs

$Co = 5.2\ Q^{0.05}\ H^{0.25}\ T\ (2.5\ Wo + I)$ 8,640

Maintenance Cost

$Cm = 2.0\ Q^{0.11}\ H^{0.41}\ G^{0.43}\ (0.49\ Wm + I)$ 5,610

Electrical Costs

$CE_d = (10)\ (100)\ (0.746)\ (1.32) = 985$
$CE_s = (10{,}000/2590)\ (100)\ (4724.52)\ (0.01) = 18{,}241$ 19,220

ANNUAL PROJECT COSTS

Annual Equivalent Project Cost (40 years at 6 5/8%)	$ 425,080
Operation	8,640
Maintenance and Replacement	5,610
Electricity	19,220
TOTAL ANNUAL PROJECT COST	$ 458,550

WILLOW CREEK SITE A

STORAGE: 15,000 AF FIRM ANNUAL YIELD: 7,000 AF/YR NUMBER OF PUMPS: 3

Discharge: 12.5 cfs/pump Total Head: 145 ft
Discharge Length: 6,600 ft Diameter: 45 in
Surface Area of Reservoir: 580 ac
T = 26 weeks I = 1.71 Wo = $5.50
Semiattended Plant Wm = $6.00
January 1977 Prices

PROJECT COSTS

	Unit	Quantity	Unit Cost	Rounded Total Cost
Dam Structure				
Complete Structure	CY	680,000	$ 2.50	$1,700,000
Land Rights	AC	640	150.00	96,000
SUBTOTAL				$1,796,000
Pumping Plant				
Pumps and Prime Movers				$ 119,800
Structures and Improvements				214,200
Accessory Electrical Equipment				70,300
Miscellaneous Equipment				13,000
Switchyard 69KV 731 KVA				90,000
Outlet Manifold				59,900
SUBTOTAL				$ 567,200
Discharge Line				
Reinforced Concrete Pipe	FT	6,600	67.00	$ 442,200
Excavation	CY	17,875	3.75	67,000
Backfill				
Class A	CY	6,910	10.00	69,100
Class C	CY	10,540	2.00	21,100
SUBTOTAL				$ 599,400

Diversion Structure				
Concrete	CY	250	3.00	$ 75,000
Steel	LBS	20,000	0.40	8,000
Excavation	CY	1,400	3.75	5,200
Backfill	CY	300	10.00	3,000
Riprap	CY	40	15.00	600
SUBTOTAL				$ 91,800
Sump				
Concrete	CY	27	350.00	$ 9,400
Excavation	CY	2,500	1.00	2,500
SUBTOTAL				$ 11,900
Total Direct Field Costs				$3,066,300
Contingencies	25%			766,600
Engineering	15%			574,900
TOTAL PROJECT COST				$4,407,800

ANNUAL COSTS

Operation Costs

$$Co = 5.2\ Q^{0.05}\ H^{0.25}\ T\ (2.5\ Wo + I)$$ 8,290

Maintenance Cost

$$Cm = 2.0\ Q^{0.11}\ H^{0.41}\ G^{0.43}\ (0.49\ Wm + I)$$ 4,440

Electrical Costs

$CE_d = (3)\ (200)\ (.746)\ (1.32) = 591$

$CE_s = (7{,}000/5610)\ (200)\ (4724.52)\ (0.01) = 11{,}790$

12,380

ANNUAL PROJECT COSTS

Annual Equivalent Project Cost (40 years at 6 5/8%)	$ 316,330
Operation	8,290
Maintenance and Replacement	4,440
Electricity	12,380
TOTAL ANNUAL PROJECT COST	$ 341,440

WILLOW CREEK SITE A

STORAGE: 10,000 AF FIRM ANNUAL YIELD: 5,000 AF/YR NUMBER OF PUMPS: 2

Discharge: 13.6 cfs/pump Total Head: 110 ft
Discharge Length: 6,600 ft Diameter: 42 in
Surface Area of Reservoir: 420 ac
T = 26 weeks I = 1.71 Wo = $5.50
Semiattended Plant Wm = $6.00
January 1977 Prices

PROJECT COSTS

	Unit	Quantity	Unit Cost	Rounded Total Cost
Dam Structure				
Complete Structure	CY	470,000	$ 2.50	$1,175,000
Land Rights	AC	500	150.00	75,000
SUBTOTAL				$1,250,000
Pumping Plant				
Pumps and Prime Movers				$ 84,400
Structures and Improvements				146,900
Accessory Electrical Equipment				44,500
Miscellaneous Equipment				10,100
Switchyard 69KV 731 KVA				85,000
Outlet Manifold				42,200
SUBTOTAL				$ 413,100
Discharge Line				
Reinforced Concrete Pipe	FT	6,600	61.00	$ 402,600
Excavation	CY	16,255	3.75	61,000
Backfill				
Class A	CY	6,200	10.00	62,000
Class C	CY	9,800	2.00	19,600
SUBTOTAL				$ 545,200

Diversion Structure				
Concrete	CY	250	3.00	$ 75,000
Steel	LBS	20,000	0.40	8,000
Excavation	CY	1,400	3.75	5,200
Backfill	CY	300	10.00	3,000
Riprap	CY	40	15.00	600
SUBTOTAL				$ 91,800
Sump				
Concrete	CY	18	350.00	$ 6,300
Excavation	CY	2,000	1.00	2,000
SUBTOTAL				$ 8,300
Total Direct Field Costs				$2,308,400
Contingencies	25%			577,100
Engineering	15%			432,800
TOTAL PROJECT COST				$3,318,300

ANNUAL COSTS

Operation Costs	
$Co = 5.2\ Q^{0.05}\ H^{0.25}\ T\ (2.5\ Wo + I)$	7,990
Maintenance Cost	
$Cm = 2.0\ Q^{0.11}\ H^{0.41}\ G^{0.43}\ (0.49\ Wm + I)$	3,580
Electrical Costs	
$CE_d = (2)\ (200)\ (0.746)\ (1.32) = 394$	8,110
$CE_s = (5{,}000/6120)\ (200)\ (4724.52)\ (0.01) = 7{,}720$	

ANNUAL PROJECT COSTS

Annual Equivalent Project Cost (40 years at 6 5/8%)	$ 238,140
Operation	7,990
Maintenance and Replacement	3,580
Electricity	8,110
TOTAL ANNUAL PROJECT COST	$ 257,820

WILLOW CREEK SITE A

STORAGE: 10,000 AF FIRM ANNUAL YIELD: 6,000 AF/YR NUMBER OF PUMPS: 4

Discharge: 6.8 cfs/pump Total Head: 110 ft
Discharge Length: 6,600 ft Diameter: 42 in
Surface Area of Reservoir: 420 ac
T = 26 weeks I = 1.71 Wo = $5.50
Semiattended Plant Wm = $6.00
January 1977 Prices

PROJECT COSTS

	Unit	Quantity	Unit Cost	Rounded Total Cost
Dam Structure				
Complete Structure	CY	470,000	$ 2.50	$1,175,000
Land Rights	AC	500	150.00	75,000
SUBTOTAL				$1,250,000
Pumping Plant				
Pumps and Prime Movers				$ 84,400
Structures and Improvements				146,900
Accessory Electrical Equipment				58,600
Miscellaneous Equipment				10,100
Switchyard 69KV 731 KVA				85,000
Outlet Manifold				42,200
SUBTOTAL				$ 427,200
Discharge Line				
Reinforced Concrete Pipe	FT	6,600	61.00	$ 402,600
Excavation	CY	16,255	3.75	61,000
Backfill				
Class A	CY	6,210	10.00	62,000
Class C	CY	9,800	2.00	19,600
SUBTOTAL				$ 545,200

Diversion Structure				
Concrete	CY	250	3.00	$ 75,000
Steel	LBS	20,000	0.40	8,000
Excavation	CY	1,400	3.75	5,200
Backfill	CY	300	10.00	3,000
Riprap	CY	40	15.00	600
SUBTOTAL				$ 91,800
Sump				
Concrete	CY	32	350.00	$ 11,300
Excavation	CY	2,900	1.00	2,900
SUBTOTAL				$ 14,200
Total Direct Field Costs				$2,328,400
Contingencies	25%			582,100
Engineering	15%			436,600
TOTAL PROJECT COST				$3,347,100

ANNUAL COSTS

Operation Costs

$$Co = 5.2\ Q^{0.05}\ H^{0.25}\ T\ (2.5\ Wo + I)$$ 7,990

Maintenance Cost

$$Cm = 2.0\ Q^{0.11}\ H^{0.41}\ G^{0.43}\ (0.49\ Wm + I)$$ 3,870

Electrical Costs

$CE_d = (4)\ (100)\ (.746)\ (1.32) = 394$

$CE_s = (6{,}000/3060)\ (100)\ (4724.52)\ (0.01) = 9{,}264$

9,660

ANNUAL PROJECT COSTS

Annual Equivalent Project Cost (40 years at 6 5/8%)	$ 240,200
Operation	7,990
Maintenance and Replacement	3,870
Electricity	9,660
TOTAL ANNUAL PROJECT COST	$ 261,720